

VARIABLE-DENSITY YIELD TABLES FOR MANAGED STANDS OF NATURAL SLASH PINE

Abstract. -- This paper presents tables of yield for thinned, or managed, stands of slash pine. It includes both predicted yields for given stand conditions and projected yields from known stocking levels. In the development of yield projections, a new technique is formulated that will be useful in stand management.

As an aid to the management of natural slash pine (*Pinus elliottii* var. *elliottii*) timber stands, this paper presents cubic- and board-foot yield estimates for various age-site-density combinations. It includes both predicted yields and estimates of future yields as projected from known stocking levels. The yield estimates were developed from data gathered from a series of growing space plots maintained at assigned residual densities for 10 years. The predicted yields thus apply in stands that have been under a specific plan of management and have been thinned one or more times. This fact distinguishes these tables of yield from existing slash pine yield estimates, which were all derived from unthinned, or unmanaged, stands.

METHODS

In 1955, the Southeastern Forest Experiment Station and several cooperators established 176 one-fourth-acre plots in natural slash pine stands to evaluate growth and total yield as influenced by age, site, and stand density. These plots were set up in stands that showed no visible evidence of severe burning, insect or disease damage, thinning, or having been worked for naval stores. The plots ranged from Tampa and throughout east and west Florida to as far north as Cordele and Savannah, Georgia. To obtain the range of densities needed for growth analysis, a number of plots were cut to specified residual basal areas at time of plot installation. Plot remeasurement has been at 5-year intervals, with all plots being cut to the assigned basal area at each measurement. Measurement data at the beginning and end of the second 5-year growth period were used in the analysis. Data from 82 plots were available for the yield analyses (table 1).

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Table 1. --Distribution of plots as arrayed at the beginning of the growth period

Age	Site index	Basal area (square feet)						Totals
		50	75	100	125	150	175	
----- <u>Number</u> -----								
20	60							
	70	1						1
	80	1						1
	90			3				3
	100		3		1			4
30	60		1					1
	70	3	1	3				7
	80	3	3	6	3	1		16
	90	1	1	3	2	2		9
	100		1		2			3
40	60							
	70		1					1
	80	4	2	1	2	1		10
	90	1	3	5	5		2	16
	100	1	1			1		3
50	60							
	70							
	80	1			1			2
	90				1			1
	100				1			1
60	60							
	70						1	1
	80	1	1					2
	90							
	100							
Totals		17	18	21	18	5	3	82

SITE INDEX ANALYSIS

Original height measurement data from the 176 plots were used for a site index analysis. Using the standard regression model, the following height equation was developed:

$$\text{Log of height} = 2.0105 - 6.1028 \frac{1}{\text{age}} \quad (1)$$

where log = common logarithm.

The 50-year curves in figure 1 were developed from this equation. For the yield analysis, the site index of each plot was read from these curves.

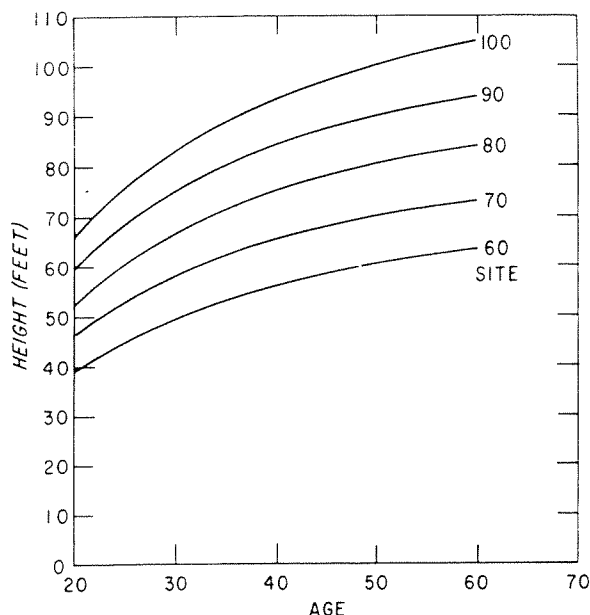


Figure 1.--Site index curves (50-year basis) for stands of natural slash pine in Georgia and Florida.

VOLUME CALCULATIONS

From the sample tree data, a height-diameter curve was constructed for each plot by using the following regression model:

$$\text{Log } H = b_0 + b_1 \frac{1}{D}$$

where log = common logarithm,

H = total height in feet,

and D = diameter at breast height.

After a height for each diameter class on the plot was established, the following equations¹ were used to calculate volumes for each diameter class:

$$\text{CFV} = 0.002853D^2H - 0.976$$

$$\text{BFV} = 0.1495D^2H - 60.25$$

where CFV = cubic volume for all trees 4.6 inches d.b.h. and larger to a 4-inch top diameter, outside bark,

BFV = board-foot volume, International $\frac{1}{4}$ -inch scale, to an 8-inch top diameter, outside bark,

and D and H are as above. The threshold diameter for sawtimber was 9.6 inches.

¹Cooper, Robert W., and Olson, David F., Jr. Volume determinations for second-growth slash and longleaf pine in northeast Florida. USDA Forest Serv. Southeast. Forest Exp. Sta. Pap. 92, 11 pp. 1958.

In each instance, plot volumes were obtained by applying diameter class volumes to the observed diameter distributions and summing the results. Basal area totals were derived by summing the basal areas of individual trees.

Total growth per plot was obtained by subtracting 1961 plot data from the 1966 data. Periodic annual growth was then calculated by dividing the total growth value by the length of the growth period.

YIELD ANALYSES²

An estimate of expected yields for timber stands of given age, site, and density is necessary for efficient forest management planning. A further valuable aid would be the ability to forecast production through time for these stands of known age, site, and density. The following equations, developed by multiple regression technique from observed measurement data of the plots outlined in table 1, establish this capability:

$$\text{LnY}_2 = 5.98812 - \frac{121.713}{S} - \frac{19.758}{A_2} + 4.632\left(1 - \frac{A_1}{A_2}\right) + 0.89683(\text{LnB}_1)\left(\frac{A_1}{A_2}\right) \quad (2)$$

$$R^2 = 0.9660 \quad \text{SE} = 0.0915$$

$$\text{LnY} = 5.98812 - \frac{121.713}{S} - \frac{19.758}{A} + 0.89683(\text{LnB}) \quad (3)$$

$$\text{LnB}_2 = \text{LnB}_1\left(\frac{A_1}{A_2}\right) + 5.1649\left(1 - \frac{A_1}{A_2}\right) \quad (4)$$

$$\text{BFY} = 1236.125 - 186.16011(B) + 7.31406(\text{CFV}) \quad (5)$$

$$R^2 = 0.9441 \quad \text{SE} = 1958$$

where Ln = natural logarithm,

A = any given age,

B = any given basal area,

A₁ = initial age,

A₂ = terminal age,

B₁ = initial basal area,

B₂ = terminal basal area (projected yield),

CFV = cubic-foot stocking

² All yield analyses were performed by Dr. J. L. Clutter, School of Forest Resources, University of Georgia, Athens, Georgia.

S = site index (50-year basis),

Y = cubic-foot yield,

Y₂ = projected cubic-foot yield,

and BFY = board-foot yield.

Equation (2) projects cubic yield through time from known stand conditions to a designated later age (table 2).

Equation (3) was developed from equation (2) by setting $A_1 = A_2 = A$. This in effect is a projection period of zero length, and results in predicted yields (table 3).

Equation (4) projects basal area stocking for stands of given conditions (table 2).

Equation (5) can be used to predict board-foot yields for given stand conditions (table 3). By using projected basal area and cubic-foot values, this equation can also be used to project board-foot yields (table 4).

Table 2. --Cubic-foot and basal area yields as projected from various base ages and stockings

From age	To age	Site index					Projected basal area	Site index					Projected basal area
		60	70	80	90	100		60	70	80	90	100	
		----- Cu. ft. -----					Sq. ft.	----- Cu. ft. -----					Sq. ft.
50 SQ. FT. BASAL AREA							75 SQ. FT. BASAL AREA						
20	20	652	871	1,083	1,282	1,468	50	938	1,253	1,558	1,844	2,111	75
	30	1,318	1,761	2,189	2,592	2,967	76	1,680	2,244	2,789	3,303	3,781	99
	40	1,874	2,504	3,112	3,685	4,219	94	2,248	3,003	3,732	4,420	5,060	115
	50	2,315	3,093	3,843	4,551	5,210	106	2,677	3,577	4,445	5,264	6,026	125
30	30	906	1,211	1,505	1,782	2,040	50	1,304	1,742	2,165	2,564	2,935	75
	40	1,415	1,891	2,350	2,783	3,185	68	1,859	2,484	3,087	3,655	4,184	93
	50	1,849	2,470	3,070	3,635	4,162	83	2,299	3,072	3,818	4,522	5,176	105
40	40	1,069	1,428	1,774	2,101	2,405	50	1,537	2,054	2,552	3,023	3,460	75
	50	1,477	1,973	2,452	2,904	3,324	64	1,975	2,639	3,280	3,884	4,446	89
100 SQ. FT. BASAL AREA							125 SQ. FT. BASAL AREA						
20	20	1,214	1,622	2,016	2,387	2,733	100	1,483	1,982	2,463	2,916	3,338	125
	30	1,995	2,665	3,313	3,923	4,491	121	2,280	3,046	3,785	4,483	5,132	140
	40	2,557	3,417	4,246	5,028	5,756	132	2,826	3,776	4,693	5,557	6,362	148
	50	2,968	3,966	4,928	5,836	6,681	140	3,215	4,296	5,339	6,322	7,238	153
30	30	1,688	2,255	2,802	3,318	3,799	100	2,061	2,754	3,423	4,053	4,640	125
	40	2,256	3,014	3,745	4,435	5,078	115	2,621	3,502	4,352	5,154	5,900	136
	50	2,684	3,587	4,458	5,279	6,043	125	3,027	4,044	5,026	5,952	6,814	143
40	40	1,990	2,658	3,304	3,912	4,479	100	2,430	3,247	4,036	4,779	5,471	125
	50	2,428	3,244	4,032	4,774	5,466	112	2,850	3,808	4,732	5,603	6,415	134

Table 3.--Cubic- and board-foot yields for stands of natural slash pine

Age	Site index	Basal area (square feet)											
		50		75		100		125		150		175	
		Cu. ft.	Bd. ft.	Cu. ft.	Bd. ft.	Cu. ft.	Bd. ft.	Cu. ft.	Bd. ft.	Cu. ft.	Bd. ft.	Cu. ft.	Bd. ft.
20	60	652	0	938	0	1,214	0	1,483	0	1,746	0	2,005	0
	70	871	0	1,253	0	1,622	0	1,982	0	2,334	0	2,680	0
	80	1,083	0	1,558	0	2,016	0	2,463	0	2,900	0	3,330	0
	90	1,282	1,306	1,844	764	2,387	81	2,916	0	3,434	0	3,943	0
	100	1,468	2,664	2,111	2,718	2,733	2,609	3,338	2,384	3,932	2,067	4,514	1,677
30	60	906	0	1,304	0	1,688	0	2,061	0	2,428	0	2,788	0
	70	1,211	785	1,742	16	2,255	0	2,754	0	3,244	0	3,725	0
	80	1,505	2,936	2,165	3,109	2,802	3,116	3,423	3,002	4,031	2,796	4,629	2,513
	90	1,782	4,963	2,564	6,025	3,318	6,890	4,053	7,613	4,774	8,226	5,481	8,748
	100	2,040	6,850	2,935	8,740	3,799	10,405	4,640	11,907	5,465	13,282	6,275	14,554
40	60	1,069	0	1,537	0	1,990	0	2,430	0	2,862	0	3,286	0
	70	1,428	2,371	2,054	2,296	2,658	2,064	3,247	1,717	3,824	1,282	4,391	775
	80	1,774	4,906	2,552	5,943	3,304	6,784	4,036	7,483	4,753	8,073	5,457	8,572
	90	2,101	7,296	3,023	9,381	3,912	11,234	4,779	12,920	5,628	14,475	6,462	15,924
	100	2,405	9,521	3,460	12,583	4,479	15,378	5,471	17,981	6,443	20,436	7,398	22,768
50	60	1,179	555	1,697	0	2,196	0	2,683	0	3,159	0	3,628	0
	70	1,576	3,455	2,267	3,856	2,934	4,082	3,585	4,183	4,221	4,187	4,847	4,110
	80	1,959	6,253	2,817	7,881	3,647	9,293	4,455	10,548	5,246	11,682	6,024	12,717
	90	2,319	8,891	3,336	11,677	4,318	14,205	5,275	16,549	6,212	18,749	7,133	20,831
	100	2,655	11,348	3,820	15,210	4,944	18,779	6,039	22,136	7,112	25,329	8,166	28,387

Table 4.--Projected board-foot yields with associated basal area yields

From age	To age	Site index					Projected basal area	Site index					Projected basal area
		60	70	80	90	100		60	70	80	90	100	
		----- <u>Bd. ft.</u> -----					<u>Sq. ft.</u>	----- <u>Bd. ft.</u> -----					<u>Sq. ft.</u>
50 SQ. FT. BASAL AREA							75 SQ. FT. BASAL AREA						
20	20	0	0	0	1,306	2,664	50	0	0	0	764	2,718	75
	30	0	0	3,111	6,060	8,805	76	0	0	3,117	6,874	10,372	99
	40	0	2,135	6,582	10,773	14,676	94	0	1,873	7,206	12,234	16,915	115
	50	0	4,117	9,608	14,785	19,606	106	0	4,182	10,533	16,521	22,096	125
30	30	0	785	2,936	4,963	6,850	50	0	16	3,109	6,025	8,740	75
	40	0	2,333	5,691	8,856	11,803	68	0	2,145	6,554	10,712	14,583	93
	50	0	3,939	8,326	12,461	16,311	83	0	4,113	9,568	14,712	19,501	105
40	40	0	2,371	4,906	7,296	9,521	50	0	2,296	5,943	9,381	12,583	75
	50	78	3,709	7,212	10,515	13,590	64	0	3,999	8,685	13,104	17,217	89
100 SQ. FT. BASAL AREA							125 SQ. FT. BASAL AREA						
20	20	0	0	0	81	2,609	100	0	0	0	0	2,384	125
	30	0	0	3,030	7,492	11,647	121	0	0	2,889	7,989	12,736	140
	40	0	1,598	7,665	13,385	18,711	132	0	1,321	8,027	14,349	20,235	148
	50	0	4,195	11,237	17,876	24,057	140	0	4,181	11,809	19,001	25,698	153
30	30	0	0	3,116	6,890	10,405	100	0	0	3,002	7,613	11,907	125
	40	0	1,867	7,219	12,264	16,961	115	0	1,536	7,754	13,616	19,075	136
	50	0	4,183	10,552	16,557	22,148	125	0	4,194	11,376	18,146	24,451	143
40	40	0	2,064	6,784	11,234	15,738	100	0	1,717	7,483	12,920	17,981	125
	50	0	4,144	9,905	15,336	20,393	112	0	4,194	10,955	17,330	23,264	134

Equation (4) employs no measure of site index in the projection of basal area. The equation was developed by integrating a basal area growth equation, which was formulated by multiple regression analysis of the observed plot data. Because the study design forced a strong negative correlation between trees per acre and site, multiple regression correlations showed a weak negative correlation between site and basal area growth. In the basal area growth analysis, site was nonsignificant, and consequently it does not appear in the projection equation.

USE AND APPLICATION

As an example of the use of the equations, if we have measured values of age, site index, and basal area stocking, we can:

1. Enter equation (3) with these values, and predict cubic yield.
2. Enter equation (5) with the measured basal area and the predicted cubic volume yield, and predict board-foot yield.
3. Enter equation (2) with the observed stand values, and project cubic yield to a future age.
4. Enter equation (4) with the observed stand values, and project basal area stocking to a designated future age.
5. Enter equation (5) with projected values of basal area and cubic volume, and project board-foot yield.

To illustrate the use of the tables of projection, with a given age and basal area stocking, cubic yields at future ages can be read from table 2. For example, with 50 square feet of basal area at age 20 the expected yield at age 30 would be 1,318 cubic feet on site 60 and 2,967 cubic feet on site 100, with a projected basal area yield of 76 square feet for all sites. The apparent anomaly of the same projected basal area yield for all sites is, to repeat, the result of a difference in number of trees per acre--more trees being required to produce 50 square feet of basal area on site 60 than on site 100. The effect of site is offset by this difference in number of trees per acre.

Yields as calculated by these equations can be applied with confidence to thinned stands throughout the range of typical slash pine in Georgia and Florida. The yields can be expected to approximate the volumes found in unthinned stands, but should be used with caution under these conditions because, at a given basal area stocking, the thinned stand will probably have a greater average height and hence more volume.

Frank A. Bennett, Principal Silviculturist
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